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COMBUSTION BYPRODUCTS RECYCLING CONSORTIUM

Ashlines

a program of the National Mine Land Reclamation Center at West Virginia University in cooperation with the U.S. Department of Energy - National Energy Technology Laboratory www.netl.doe.gov

To promote and support the commercially viable and environmentally sound recycling of coal combustion byproducts for productive uses through scientific research, development, and field testing.

Manufacturing Fired Bricks with Class F Fly Ash from Illinois Basin Coals

Mei-In Melissa Chou, P.I.

(L to R) Sheng-Fu Joseph Chou , Mei-In Melissa Chou, and a Colonial Brick Company representative examine bricks manufactured with Class F fly ash. The company is testing the manufacture of the bricks on a commercial scale. Photo courtesy of ISGS.

Researchers at the Illinois State Geological Survey (ISGS) and the University of Illinois are working with brick manufacturers to develop high-quality, marketable brick products using large volumes of Class F fly ash. The fly ash is generated from power plants burning Illinois coals.

In this fired brick-making process, fly ash is used as a raw material to substitute for part of the clay and shale, which are the two main raw materials of a conventional brick. Test bricks produced so far have met or exceeded ASTM commercial specifications.

Objectives of the project included assessing the technical, economic, and environmental suitability of fly ash for commercial production of fired bricks and conducting a public outreach campaign to promote the use of similar fly ash from other adequate sources by brick producers.

The project was funded by the U.S. Department of Energy-National Energy Technology Laboratory and the Combustion Byproducts Recycling Consortium. Additional partners included the Colonial Brick Company and Cinergy PSI's Cayuga Power Generation Station (CPSIC).

Project Description

More than six million tons of Class F fly ash are generated from

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Manufacturing Fired Bricks with Class F Fly Ash from Illinois Basin Coals *(continued from page 1)*

burning about 100 million tons of Illinois Basin coal each year. Most of this fly ash is ponded or landfilled, but could be readily available for making fired bricks. Nevertheless, until the brick industry gains more confidence in using fly ash as a raw material for brick production, evaluation and testing will be needed on a case-by-case basis.

In this project, researchers determined if the Class F fly ash produced by Cinergy PSI's Cayuga Power Generation Station, which burns Illinois Basin coals from Illinois and Indiana, is a viable raw material for brick production at Colonial Brick Company, a brick plant in Indiana near the Illinois border. Project tasks included:

- sample acquisition;
- characterization of raw materials,
- production of commercial-size green bricks;
- evaluation of preliminary in-plant firing;
- commercial-scale production;
- economic assessment; and
- an environmental feasibility study.

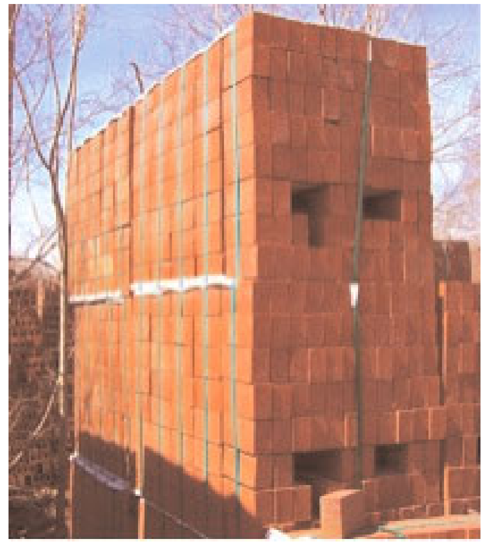
Results

To prepare for the commercial-scale production test runs, pre-cursor tests were conducted at the ISGS bench-scale facility, and more than 80 commercial-size test bricks of various formulations were made. In addition to the paving bricks containing fly ash at 10, 20, 30, 40, and 50 percent of volume balanced with clay and shale material, researchers at the ISGS also made three-hole building bricks containing fly ash up to 60 percent of volume (about 56 percent of weight).

Researchers fired a set of these mold-pressed green bricks using the ISGS kiln. They also fired another set of these mold-pressed green bricks at the brick plant as part of a commercial firing. Both firings produced high-quality, attractive, and strong paving and building bricks.

The brick plant conducted two commercial-scale production test runs of paving bricks (2,000 bricks per run – including extrusion and firing). Run I produced paving bricks with a raw material formulation containing fly ash at 20 percent of volume (about 14 percent of weight) balanced with shale material at 80 percent of volume. Run II was composed of a mix of fly ash at 20 percent of volume, shale at 60 percent of volume, and clay at 20 percent of volume. These runs produced high-quality paving bricks with a yield of 75 and 100 percent for Runs I and II, respectively.

The engineering properties of these bricks either met or exceeded ASTM standards for commercial



Two thousand paving bricks with fly ash from commercial scale-up production (Run II).

application. For example, their compressive strength was three times greater than the minimum allowable strength.

Mold-pressed paving bricks produced at the ISGS bench-scale facility before firing (A) and after firing (B) are shown below. The brick plant also conducted four

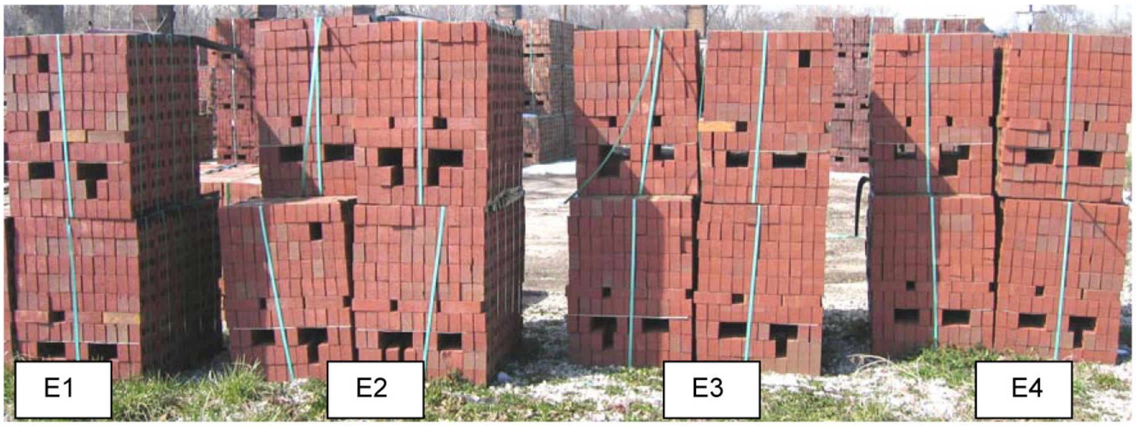
(A)

paving bricks before firing

(B)

paving bricks after firing

Manufacturing Fired Bricks with Class F Fly Ash from Illinois Basin Coals (continued from page 2)



Four batches of fired building bricks produced from scale-up production test runs with fly ash inputs at 0, 20, 30, and 40 percent by volume.

commercial-scale production test runs of three-hole building bricks (2,000 bricks per run, including extrusion and firing).

The bricks contained fly ash levels of 0, 20, 30, and 40 percent of volume (about 37 percent of weight), labeled as E1, E2, E3, and E4 above. The run with zero percent fly ash (E1) was used as a control run to mimic the standard production formulation for the brick plant. Each run produced strong and attractive bricks with a commercially acceptable yield of greater than 95 percent. The engineering properties of these bricks either met or exceeded ASTM standards for commercial application.

An evaluation indicated that it would be economically feasible for the participating brick plant to use CPSIC's fly ash as a raw material in commercial brick production. An environmental feasibility leaching study showed that, similar to the regular commercial brick, the fly ash containing bricks are environmentally safe construction products.

The number of bricks produced in the U.S. has steadily increased each year. In 2001, nationwide production was estimated at 8.3 billion SBE (standard brick equivalents). By the year 2003, it had increased to 8.6 billion. In 2004, it reached 9.3 billion, which would weigh 23.25 million tons (at five pounds per brick). The amount of ash that could be consumed, using as a substitute raw material, will depend on the brick plant's production rate and the amount of ash that can be successfully incorporated into the brick body.

At the current brick plant production rate of 16 million bricks per year, utilizing 40 percent by weight of fly ash per brick, an annual consumption of approximately 14,000 tons of fly ash could be achieved.

Successful commercial manufacture of bricks containing fly ash could provide a growing and profitable market for Illinois Basin coal ashes generated. It could also encourage electric power generation companies to continue to use Illinois Basin coals, and will help provide a reliable and inexpensive new source of raw materials for fired brick manufacturing.

Another brick plant in Indiana has expressed an interest of this technology. Researchers at the ISGS will continue to use their expertise and brick-making facilities to assist companies who are interested in developing commercial-scale bricks that contain substantial amounts of fly ash.

For More Information, contact Mei-In Melissa Chou, Illinois State Geological Survey, at (217) 244-0312, or by e-mail to chou@isgs.uiuc.edu. The complete project report (#02-CBRC-M12) is expected to be available later this fall on the CBRC's Web site at http://wvwri.nrcce.wvu.edu/ programs/cbrc.

Arsenic and Selenium Leached from CCBs: Is it Going Anywhere?

Bradley C. Paul, Ph.D., P.I.

Caney Fork River, Tennessee. Photo courtesy of the U.S. Army Corps of Engineers.

Coal combustion byproducts (CCBs) make suitable fills for use in a variety of settings. In many instances, concerns arise that these materials might leach toxic ultra-trace elements, such as arsenic and selenium, into groundwater supplies with deleterious effects.

Many test procedures have been developed to characterize whether various elements may leach from CCBs, but site characteristics have been heavily ignored. Specifically, the question of whether elements once leached from CCBs would actually remain in solution has not been addressed. Obviously, an element once leached from a CCB would not be a water contaminant if it were not in the water.

The objective of a research project funded by U.S. Department of Energy-National Energy Technology Laboratory and the Combustion Byproducts Recycling Consortium (CBRC) examined whether soils and degraded rocks common to the road-cut and mine environments in which CCBs are placed would allow arsenic and selenium to remain in the water if leaching occurs. The goal is to provide an environmental risk assessment check seldom used in today's permitting reviews.

Basis for Environmental Concern About Arsenic and Selenium in CCBs

Arsenic and selenium are two trace elements that have often been raised as an environmental and

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Arsenic and Selenium Leached from CCBs: Is it Going Anywhere? (continued from page 4)

health concern in relation to CCBs. Coal itself is a product of plant and soil sedimentation in ancient swamp-like environments. Of course, the fossilized plant portion of coal will burn in boilers today, but the swamp soils mixed in with the plant material will not. These ancient swamp soils become the feedstock for fly and bottom ash left as residue from the coal combustion process.

Taken as a whole, these ash products are, not surprisingly, quite similar in arsenic and selenium content to soil materials deposited in swamps today. Combustion temperatures can, however, alter the mineralogy and distribution of arsenic and selenium. Both trace elements have comparatively low volitalization temperatures, meaning that the elements become gaseous and tend to move with the hot flue gases. The volatile trace elements will condense on the fly ash or some of the particles used in scrubber systems as the flue gas cools.

Since only part of the ancient swamp soil is processed into fly ash, but almost all of the contained arsenic and selenium move in this direction, there will be a modest but measurable increase in trace element content in fly ash versus the original swamp soils. Further, the arsenic and selenium will tend to be deposited on the fly ash surfaces in higher concentrations, just as dust particles can be nucleation sites for rain drops.

This change in the position of the arsenic and selenium then becomes the basis of concern. Most CCBs are assessed for environmental safety on the basis of shake tests that contact fresh ash with water for a limited and single time. To the extent that arsenic and selenium have been moved and concentrated at surface leaching sites, one can see higher levels of arsenic and selenium in the leachate than one might guess from the limited arsenic and selenium content of the ash.

Leaching tests will at times give arsenic or selenium concentrations that would violate primary drinking water standards though usually not by enough to merit hazardous or hazardous like waste characterization. The apparent concern can be even worse if one places a well in a CCB fill and then measures pore water concentrations. This can be particularly true if the CCB fill is relatively tight so that the pore water is largely stagnant and unexchanged.

Concern about Arsenic and Selenium Contaminating Down-Gradient Water Resources

As a practical matter, however, the real concern would be that leachate from CCBs could contaminate down-gradient water resources enough to harm individuals or species using that water. One would not, for example, locate a water well in a tight formation that would not yield significant water. Thus, high trace element concentrations in tight, stagnant pore waters and contaminated water entering a water well are almost mutually exclusive. In the event that contaminated leachate does move out of the fill, a variety of computer programs can look at down-gradient concentrations considering the effects of dilution and dispersion.

The problem is that such models assume that trace elements once in the water will be carried and moved by the water almost indefinitely. When one realizes that much of the arsenic and selenium in fly ash was adsorbed from ancient swamp waters, one wonders why similar sediments today would not also adsorb trace elements.

Project Overview

The work funded by the CBRC considered the case of CCBs placed as fills in the bottoms of surface mines or as fill in road cuts. Samples were taken of the coal overburden formations that would be placed over CCB cells as surface mining advanced. In addition, samples were taken of the soils found around typical road cuts of southwestern Indiana.

The question being studied was whether these materials would behave as inert with respect to arsenic or selenium contaminated waters, or whether they would adsorb the arsenic and selenium out of the groundwater. There would be little chance of regional groundwater contamination if all the arsenic and selenium were adsorbed back into the rocks and soils within a few feet of being leached out.

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Arsenic and Selenium Leached from CCBs: Is it Going Anywhere? (continued from page 6)

U.S. Environmental Protection Agency procedures were used to construct adsorption isotherms for these materials. The isotherms indicated very strong adsorption tendencies, especially for arsenic. Tests were then performed on the reversibility of the adsorption.

Most of the materials showed no tendency to release measurable concentrations of arsenic or selenium as the concentration in the surrounding water fell. Those that did always released levels well below limits for drinking water, indicating that if arsenic and selenium release did occur, it would be relatively benign.

The adsorption and desorption isotherms were then used with typical two-dimensional contaminant transport computer models to assess whether CCB fills placed in contact with groundwater at mines or in road sub-bases and fills could be expected to develop leachate plumes in the down-gradient groundwater. The control model assumed no adsorption took place and the leachate source continued to release arsenic or selenium at concentrations of 0.5 ppm. Over 80 years of simulation contaminant plumes, though not especially large ones, did develop.

Refinements were then added to the model. First, retardation coefficients were derived from the isotherms. Retardation coefficients assume that the leachate front moves forward only after it has saturated the adsorption capacity of the soils. This assumption caused leachate plumes to be rather small. The final model assumed that arsenic and selenium in the source was depleted over 80 years (i.e., that the fill cannot keep putting out arsenic and selenium forever without regard to a mass balance). The model kept track of the amount of arsenic or selenium adsorbed by the soil and the amount available to move on with the water. This model indicated either no plume at all or very weak plumes extending about 20 feet in 80 years.

Essentially these models answered the question of whether arsenic or selenium from CCB fills could contaminate the groundwater by suggesting that it is not going anywhere. This is generally what is found at mine sites that have been heavily monitored. Arsenic and selenium may be released, but it seems not to go anywhere or produce plumes of any size.

Of course there are limitations to the results found here. The models considered the aquifers have isotropic hydraulic conductivity at a field scale. Such a model does not cover flow occurring on large-scale open fractures. Fracture flow can allow dye tests to carry for miles in a matter of days. Fractures have less contact surface area to adsorb arsenic and selenium. Of course, contamination is largely restricted to a single fracture if dilution or exposure to a larger adsorbing surface area is to be avoided. Thus, no plume can develop in this type of setting, and water might show arsenic or selenium contamination in one place and no effect at all only a few feet away.

The model also deals with saturated groundwater flow—i.e., the CCBs are buried beneath the surface and are submerged in groundwater. To many, this would be a worse-case scenario and something to be avoided, but the work done in this project suggests that CCBs buried at mine sites pose little risk to groundwater, even if they becomes saturated below the water table. The model does not consider the case of surface run-off, which, again, may have less contact surface area to adsorb the arsenic and selenium and may allow water to move much faster than the somewhat tight aquifers found underground at mine sites.

For more information about this project, contact Bradley C. Paul at Southern Illinois University Carbondale, Mining and Mineral Resources Engineering, at (618) 453-792, or by e-mail to paul_b@siu.edu. For the complete project report, visit the CBRC's Web site at http://wvwri.nrcce.wvu.edu/programs/cbrc. Refer to project 02-CBRC-M21.

Calendar

May 7–10, 2007

2007 World of Coal Ash...Science Applications and Sustainability

Covington's Northern Kentucky Convention Center, Cincinnati, Ohio
Organizers: American Coal Ash Association and University of Kentucky Center for Applied Energy Research

World of Coal Ash is a conference that combines the previous international symposia of the ACAA and CAER. It will focus on the science applications and sustainability of coal ash worldwide. It is planned to encompass all aspects of coal combustion products as well as gasification.

www.worldofcoalash.org.

January 29–31, 2007

American Coal Ash Association Meeting

Crown Plaza Riverfront Jacksonville, Florida
For more information: Annely Noble; 720-870-7897

www.acaa-usa.org/ASP/DirectorCalendar

June 11–13, 2007

Sustainable Construction Materials and Technologies

Coventry, U.K.
Sponsored by Coventry University and University of Wisconsin, Milwaukee

The construction materials industry is a major user of the world's resources. While enormous progress has been made towards sustainability, the scope and opportunities for further improvements are significant. This conference is intended to highlight case studies and research that show new and innovative ways of achieving sustainability of construction materials and technologies.

www.uwm.edu/dept/cbu//coventry.html

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Ashlines *is published by the Combustion Byproducts Recycling Consortium, headquartered at West Virginia University in Morgantown, WV. Would you like to be on the CBRC electronic mailing list? If so, please send an e-mail to cbrc@wvu.edu.*